Radio Editors of magazines and newspapers are hereby given permission to reprint in whole or in part, with proper credit to the Aerovox Corporation, the contents of this issue of the Aerovox Research Worker.

The Aerovox Research Worker

The Aerovox Research Worker is a monthly house organ of the Aerovox Corporation. It is published to bring to the Radio Experimenter and Engineer authoritative, first hand information on condensers and resistances for radio work.

VOL. 15, NO. 1 JANUARY, 1943

50c per year in U.S.A.
60c per year in Canada

# Design Data for *m*-Derived Type Filters

## PART III

*By the Engineering Department, Aerovox Corporation*

IN the response curve for *m*-derived band-pass filter sections (see Figure 5-A in Part I, Sept.-Oct. 1942 issue), $f_1$ and $f_2$ are respectively the lower and upper cut-off frequencies marking the edges of the pass band, while $f_{1\infty}$ and $f_{2\infty}$ are respectively the lower and upper frequencies of maximum attenuation (minimum transmission). Separation between the $f_1$ frequencies and the $f_2$ frequencies will determine the steepness of the transmission curve at the borders of the pass band.

### BAND WIDTH

Width of the pass band is governed by the separation between $f_1$ and $f_2$ and may be set at a desired value by the designer in accordance with the desired band of frequencies to be transmitted by the filter. The geometric mean of the two cut-off frequencies is the mid-frequency, designated $f_m$, and is equal to the square root of $f_1 f_2$. The band-width values given in the tables accompanying this article are obtained from the formula $(f_2-f_1)/f_m$.

### INFINITE-ATTENUATION FREQUENCIES

The frequencies of infinite attenuation, $f_{1\infty}$ and $f_{2\infty}$, have been chosen in the accompanying tables to be spaced 5 percent from the cut-off frequencies, $f_1$ and $f_2$. This placement permits infinite attenuation at frequencies close enough to the cut-off frequencies to raise the transmission characteristic sharply without destroying attenuation at other frequencies. Closer spacing would result in a steeper curve at the cut-off frequencies while sacrificing attenuation of neighboring frequencies.

### VARIATION OF *m*

In *m*-derived band-pass sections, *m* is a complex term which depends upon both cut-off and attenuation frequencies:

$$m = \frac{\sqrt{\left(1-\frac{f_1^2}{f_{2\infty}^2}\right)\left(1-\frac{f_2^2}{f_{2\infty}^2}\right)}}{1-\left(\frac{f_1 f_2}{f_{2\infty}^2}\right)}$$

From this, it is evident that *m* varies with band width. Table I lists *m* values corresponding to the band widths given in the frequency chart, *m* varying from 0.45 to 0.95 for band widths between 0.05 and 0.9. The effect that *m* has upon the values of filter-section components may be seen by inspecting Chart III in Part I.

### FREQUENCY CHART

Chart I in this article gives values of $f_1$, $f_2$, $f_{1\infty}$, $f_{2\infty}$, and $f_m$ for twelve common band widths between 0.05 and 0.9 for both series- and shunt-derived band-pass filters. These frequencies are given in cycles per second, except in the 10-kc. and 100-kc. columns where listings are in kilocycles, and in the 1-Mc. and 10-Mc. columns where listings are in megacycles.

From this chart, all values for frequencies may be taken directly. Thus: a band-pass section with mid-frequency of 2000 and band width of 0.2 is seen to have upper and lower cut-off frequencies of 2220 and 1820 cycles, respectively, and upper and lower infinite attenuation frequencies of 2331 and 1729 cycles, respectively. A section with the same mid-frequency but with band width of 0.5 is observed to have upper and lower cut-off frequencies of 2562 and 1562 cycles, and upper and lower infinite attenuation frequencies of 2690 and 1484 cycles. *m* for the band width of 0.2, from Table I, is found to be 0.72; and for the 0.5 band width, 0.54.

TABLE I

Variation of *m* with Band Width, Band-Pass Filters

| BAND WIDTH | *m* |
|---|---|
| 0.05 | 0.95 |
| 0.1 | 0.84 |
| 0.15 | 0.78 |
| 0.2 | 0.72 |
| 0.25 | 0.71 |
| 0.3 | 0.68 |
| 0.4 | 0.59 |
| 0.5 | 0.54 |
| 0.6 | 0.52 |
| 0.7 | 0.51 |
| 0.8 | 0.45 |
| 0.9 | 0.46 |

AEROVOX PRODUCTS ARE BUILT BETTER

Printed in U. S. A.

Copyright 1943 by Aerovox Corporation

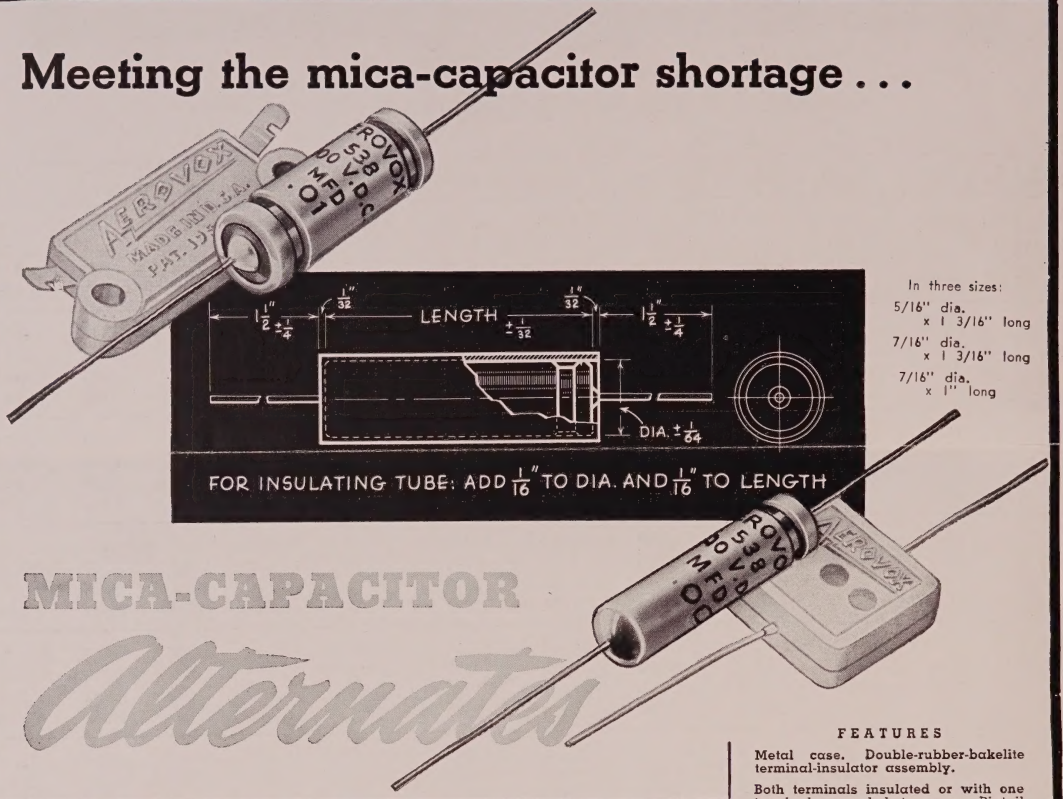
# CHART 1 — Frequency Data, Band-Pass Filters

| Band Width | $f_m$ = 100 | 1000 | 1500 | 2000 | 2500 | 3000 | 3500 | 4000 | 4500 | 5000 | 5500 | 6000 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.05 | $f_{2\infty}$ 107.6 | 1076 | 1615 | 2152 | 2691 | 3230 | 3768 | 4305 | 4844 | 5382 | 5919 | 6459 |
| | $f_2$ 102.5 | 1025 | 1538 | 2050 | 2563 | 3076 | 3589 | 4100 | 4614 | 5126 | 5637 | 6152 |
| | $f_1$ 97.5 | 975 | 1463 | 1950 | 2438 | 2926 | 3414 | 3900 | 4389 | 4876 | 5362 | 5852 |
| | $f_{1\infty}$ 92.6 | 926 | 1390 | 1852 | 2316 | 2780 | 3244 | 3705 | 4170 | 4632 | 5094 | 5560 |
| 0.1 | $f_{2\infty}$ 110 | 1103 | 1656 | 2207 | 2759 | 3311 | 3862 | 4414 | 4965 | 5519 | 6069 | 6621 |
| | $f_2$ 105 | 1051 | 1577 | 2102 | 2628 | 3153 | 3678 | 4204 | 4729 | 5256 | 5780 | 6306 |
| | $f_1$ 95 | 951 | 1427 | 1902 | 2378 | 2853 | 3328 | 3804 | 4279 | 4756 | 5230 | 5706 |
| | $f_{1\infty}$ 90 | 904 | 1356 | 1807 | 2259 | 2711 | 3162 | 3614 | 4065 | 4518 | 4969 | 5421 |
| 0.15 | $f_{2\infty}$ 113 | 1132 | 1698 | 2264 | 2829 | 3396 | 3961 | 4527 | 5093 | 5660 | 6225 | 6791 |
| | $f_2$ 108 | 1078 | 1617 | 2156 | 2694 | 3234 | 3773 | 4312 | 4851 | 5391 | 5929 | 6468 |
| | $f_1$ 93 | 928 | 1392 | 1856 | 2319 | 2784 | 3248 | 3712 | 4176 | 4641 | 5104 | 5568 |
| | $f_{1\infty}$ 89 | 882 | 1322 | 1763 | 2203 | 2645 | 3086 | 3527 | 3967 | 4409 | 4849 | 5290 |
| 0.2 | $f_{2\infty}$ 115 | 1165 | 1743 | 2331 | 2899 | 3496 | 4079 | 4662 | 5245 | 5828 | 6410 | 6993 |
| | $f_2$ 110 | 1110 | 1660 | 2220 | 2761 | 3330 | 3885 | 4440 | 4995 | 5551 | 6105 | 6660 |
| | $f_1$ 90 | 910 | 1360 | 1820 | 2261 | 2730 | 3185 | 3640 | 4095 | 4551 | 5005 | 5460 |
| | $f_{1\infty}$ 86 | 865 | 1292 | 1729 | 2148 | 2594 | 3026 | 3458 | 3890 | 4324 | 4755 | 5187 |
| 0.25 | $f_{2\infty}$ 119 | 1190 | 1784 | 2379 | 2974 | 3569 | 4163 | 4759 | 5353 | 5949 | 6542 | 7138 |
| | $f_2$ 113 | 1133 | 1699 | 2266 | 2832 | 3399 | 3965 | 4532 | 5098 | 5666 | 6231 | 6798 |
| | $f_1$ 88 | 883 | 1324 | 1766 | 2207 | 2649 | 3090 | 3532 | 3973 | 4416 | 4856 | 5298 |
| | $f_{1\infty}$ 84 | 839 | 1258 | 1678 | 2097 | 2517 | 2936 | 3355 | 3774 | 4195 | 4613 | 5033 |
| 0.3 | $f_{2\infty}$ 122 | 1220 | 1829 | 2440 | 3051 | 3660 | 4270 | 4880 | 5490 | 6101 | 6710 | 7321 |
| | $f_2$ 116 | 1162 | 1742 | 2324 | 2906 | 3486 | 4067 | 4648 | 5229 | 5811 | 6391 | 6972 |
| | $f_1$ 86 | 862 | 1292 | 1724 | 2156 | 2586 | 1050 | 3448 | 3879 | 4311 | 4741 | 5172 |
| | $f_{1\infty}$ 82 | 819 | 1227 | 1638 | 2048 | 2457 | 998 | 3276 | 3685 | 4096 | 4504 | 4913 |
| 0.4 | $f_{2\infty}$ 128 | 1282 | 1921 | 2564 | 3202 | 3846 | 4487 | 5128 | 5769 | 6411 | 7051 | 7692 |
| | $f_2$ 122 | 1221 | 1830 | 2442 | 3050 | 3663 | 4273 | 4884 | 5494 | 6106 | 6715 | 7326 |
| | $f_1$ 82 | 821 | 1230 | 1642 | 2050 | 2463 | 2873 | 3284 | 3694 | 4106 | 4515 | 4926 |
| | $f_{1\infty}$ 78 | 780 | 1169 | 1560 | 1948 | 2340 | 2729 | 3120 | 3509 | 3901 | 4289 | 4680 |
| 0.5 | $f_{2\infty}$ 134.4 | 1345 | 2017 | 2690 | 3362 | 4035 | 4707 | 5380 | 6052 | 6726 | 7397 | 8070 |
| | $f_2$ 128 | 1281 | 1921 | 2562 | 3202 | 3843 | 4483 | 5124 | 5764 | 6406 | 7045 | 7686 |
| | $f_1$ 78 | 781 | 1171 | 1562 | 1952 | 2343 | 2733 | 3124 | 3514 | 3906 | 4295 | 4686 |
| | $f_{1\infty}$ 74 | 742 | 1112.5 | 1484 | 1854.4 | 2226.9 | 2596 | 2986 | 3338 | 3711 | 4080 | 4452 |
| 0.6 | $f_{2\infty}$ 141 | 1411 | 2117 | 2822 | 3528 | 4233 | 4939 | 5645 | 6350 | 7057 | 7762 | 8467 |
| | $f_2$ 134 | 1344 | 2016 | 2688 | 3360 | 4032 | 4704 | 5376 | 6048 | 6721 | 7392 | 8064 |
| | $f_1$ 74 | 744 | 1116 | 1488 | 1860 | 2232 | 2604 | 2976 | 3348 | 3721 | 4092 | 4464 |
| | $f_{1\infty}$ 71 | 707 | 1060 | 1414 | 1767 | 2120 | 2474 | 2827 | 3181 | 3535 | 3887 | 4241 |
| 0.7 | $f_{2\infty}$ 148 | 1480 | 2220 | 2961 | 3701 | 4441 | 5182 | 5922 | 6662 | 7403 | 8143 | 8883 |
| | $f_2$ 141 | 1410 | 2114 | 2820 | 3525 | 4230 | 4935 | 5640 | 6345 | 7051 | 7755 | 8460 |
| | $f_1$ 71 | 710 | 1064 | 1420 | 1775 | 2130 | 2485 | 2840 | 3195 | 3551 | 3905 | 4260 |
| | $f_{1\infty}$ 68 | 685 | 532 | 1349 | 1686 | 2024 | 2361 | 2698 | 3035 | 3374 | 3710 | 4047 |
| 0.8 | $f_{2\infty}$ 155 | 1551 | 2327 | 3102 | 3876 | 4652 | 5427 | 6203 | 6978 | 7755 | 8529 | 9305 |
| | $f_2$ 148 | 1477 | 2216 | 2954 | 3692 | 4431 | 5169 | 5908 | 6646 | 7386 | 8123 | 8862 |
| | $f_1$ 68 | 677 | 1016 | 1354 | 1692 | 2031 | 2369 | 2708 | 3046 | 3386 | 3723 | 4062 |
| | $f_{1\infty}$ 65 | 643 | 965 | 1286 | 1607 | 1930 | 2251 | 2573 | 2894 | 3217 | 3537 | 3859 |
| 0.9 | $f_{2\infty}$ 163 | 1627 | 2436 | 3255 | 4069 | 4882 | 5696 | 6510 | 7324 | 8138 | 8951 | 9765 |
| | $f_2$ 155 | 1550 | 2320 | 3100 | 3875 | 4650 | 5425 | 6200 | 6975 | 7751 | 8525 | 9300 |
| | $f_1$ 65 | 650 | 970 | 1300 | 1625 | 1950 | 2275 | 2600 | 2975 | 3251 | 3575 | 3900 |
| | $f_{1\infty}$ 62 | 618 | 922 | 1235 | 1544 | 1853 | 2161 | 2470 | 2826 | 3089 | 3396 | 3705 |

# CHART 1 — Frequency Data, Band-Pass Filters

| Band Width | $f_m$ = 6500 | 7000 | 7500 | 8000 | 8500 | 9000 | 9500 | 10 kc. | 100 kc. | 1 Mc. | 10 Mc. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.05 | $f_{2\infty}$ 6994 | 7532 | 8070 | 8608 | 9146 | 9684 | 10220 | 10.76 | 107.6 | 1.076 | 10.762 |
| | $f_2$ 6662 | 7175 | 7687 | 8200 | 8456 | 9225 | 9737 | 10.25 | 102.5 | 1.025 | 10.250 |
| | $f_1$ 6337 | 6475 | 7312 | 7800 | 8287 | 8775 | 9260 | 9.75 | 97.5 | 0.975 | 9.750 |
| | $f_{1\infty}$ 6019 | 6482 | 6945 | 7408 | 7871 | 8334 | 8797 | 9.26 | 92.6 | 0.926 | 9.262 |
| 0.1 | $f_{2\infty}$ 7169 | 7721 | 8272 | 8824 | 9375 | 9927 | 10478 | 11.03 | 110.3 | 1.103 | 11.035 |
| | $f_2$ 6831 | 7357 | 7882 | 8408 | 8933 | 9459 | 9984 | 10.51 | 105.1 | 1.051 | 10.510 |
| | $f_1$ 6181 | 6657 | 7132 | 7608 | 8083 | 8559 | 9034 | 9.51 | 95.1 | 0.951 | 9.510 |
| | $f_{1\infty}$ 5869 | 6321 | 6772 | 7224 | 7675 | 8127 | 8578 | 9.03 | 90.3 | 0.903 | 9.034 |
| 0.15 | $f_{2\infty}$ 7332 | 7896 | 8460 | 9024 | 9588 | 10152 | 10716 | 11.28 | 112.8 | 1.128 | 11.287 |
| | $f_2$ 6987 | 7525 | 8062 | 8600 | 9137 | 9675 | 10212 | 10.75 | 107.5 | 1.075 | 10.750 |
| | $f_1$ 6012 | 6475 | 6937 | 7400 | 7862 | 8325 | 8787 | 9.25 | 92.5 | 0.925 | 9.250 |
| | $f_{1\infty}$ 5707 | 6146 | 6585 | 7024 | 7463 | 7902 | 8341 | 8.78 | 87.8 | 0.878 | 8.787 |
| 0.2 | $f_{2\infty}$ 7540 | 8120 | 8700 | 9280 | 9860 | 10440 | 11020 | 11.60 | 116.0 | 1.160 | 11.602 |
| | $f_2$ 7182 | 7735 | 8287 | 8840 | 9392 | 9945 | 10497 | 11.05 | 110.5 | 1.105 | 11.050 |
| | $f_1$ 5882 | 6335 | 6787 | 7240 | 7692 | 8145 | 8597 | 9.05 | 90.5 | 0.905 | 9.050 |
| | $f_{1\infty}$ 5583 | 6013 | 6442 | 6872 | 7201 | 7731 | 8160 | 8.59 | 85.9 | 0.859 | 8.597 |
| 0.25 | $f_{2\infty}$ 7728 | 8323 | 8917 | 9512 | 10106 | 10701 | 11295 | 11.89 | 118.9 | 1.189 | 11.896 |
| | $f_2$ 7364 | 7931 | 8497 | 9064 | 9630 | 10197 | 10763 | 11.33 | 113.3 | 1.133 | 11.330 |
| | $f_1$ 5739 | 6181 | 6625 | 7064 | 7505 | 7947 | 10388 | 8.83 | 88.3 | 0.883 | 8.830 |
| | $f_{1\infty}$ 5447 | 5866 | 6285 | 6704 | 7123 | 7542 | 7961 | 8.38 | 83.8 | 0.838 | 8.388 |
| 0.3 | $f_{2\infty}$ 7917 | 8526 | 9135 | 9744 | 10353 | 10962 | 11571 | 12.18 | 121.8 | 1.218 | 12.180 |
| | $f_2$ 7540 | 8120 | 8700 | 9280 | 9860 | 10440 | 11020 | 11.60 | 116.0 | 1.160 | 11.600 |
| | $f_1$ 5590 | 6020 | 6450 | 6880 | 7310 | 7740 | 8170 | 8.60 | 86.0 | 0.860 | 8.600 |
| | $f_{1\infty}$ 5310 | 5719 | 6127 | 6536 | 6944 | 7353 | 7761 | 8.17 | 81.7 | 0.817 | 8.170 |
| 0.4 | $f_{2\infty}$ 8313 | 8953 | 9592 | 10332 | 10871 | 11511 | 12240 | 12.79 | 127.9 | 1.279 | 12.799 |
| | $f_2$ 7923 | 8533 | 9142 | 9752 | 10361 | 10971 | 11580 | 12.19 | 121.9 | 1.219 | 12.190 |
| | $f_1$ 5323 | 5733 | 6142 | 6552 | 6961 | 7371 | 7780 | 8.19 | 81.9 | 0.819 | 8.190 |
| | $f_{1\infty}$ 5057 | 5446 | 5835 | 6224 | 6613 | 7002 | 7791 | 7.78 | 77.8 | 0.778 | 7.780 |
| 0.5 | $f_{2\infty}$ 8736 | 9408 | 10080 | 10752 | 11424 | 12096 | 12768 | 13.44 | 134.4 | 1.344 | 13.440 |
| | $f_2$ 8320 | 8960 | 9600 | 10240 | 10880 | 11520 | 12160 | 12.80 | 128.0 | 1.280 | 12.800 |
| | $f_1$ 5070 | 5460 | 5850 | 6240 | 6630 | 7020 | 7410 | 7.80 | 78.0 | 0.780 | 7.800 |
| | $f_{1\infty}$ 4816 | 5187 | 5557 | 5928 | 6298 | 6669 | 7039 | 7.41 | 74.1 | 0.741 | 7.410 |
| 0.6 | $f_{2\infty}$ 9171 | 9877 | 10580 | 11288 | 11993 | 12699 | 13404 | 14.11 | 141.1 | 1.411 | 14.112 |
| | $f_2$ 8736 | 9408 | 10080 | 10752 | 11424 | 12096 | 12768 | 13.44 | 134.4 | 1.344 | 13.440 |
| | $f_1$ 4836 | 5208 | 5580 | 5952 | 6324 | 6696 | 7068 | 7.44 | 74.4 | 0.744 | 7.440 |
| | $f_{1\infty}$ 4589 | 4942 | 5295 | 5648 | 6001 | 6354 | 6707 | 7.06 | 70.6 | 0.706 | 7.068 |
| 0.7 | $f_{2\infty}$ 9613 | 10353 | 11092 | 11832 | 12581 | 13311 | 14050 | 14.79 | 147.9 | 1.479 | 14.794 |
| | $f_2$ 9158 | 9863 | 10567 | 11272 | 11976 | 12681 | 13385 | 14.09 | 140.9 | 1.409 | 14.090 |
| | $f_1$ 4608 | 4963 | 5317 | 5672 | 6026 | 6381 | 6735 | 7.09 | 70.9 | 0.709 | 7.090 |
| | $f_{1\infty}$ 4374 | 4711 | 5047 | 5384 | 5720 | 6057 | 6393 | 6.73 | 67.3 | 0.673 | 6.735 |
| 0.8 | $f_{2\infty}$ 10075 | 10850 | 11625 | 12400 | 13175 | 13950 | 14725 | 15.50 | 155.0 | 1.550 | 15.503 |
| | $f_2$ 9594 | 10332 | 11070 | 11808 | 12546 | 13284 | 14020 | 14.76 | 147.6 | 1.476 | 14.765 |
| | $f_1$ 4392 | 4732 | 5070 | 5408 | 5746 | 6084 | 6422 | 6.76 | 67.6 | 0.676 | 6.765 |
| | $f_{1\infty}$ 4173 | 4494 | 4815 | 5136 | 5457 | 5778 | 6099 | 6.42 | 64.2 | 0.642 | 6.426 |
| 0.9 | $f_{2\infty}$ 10556 | 11368 | 12180 | 12992 | 13804 | 14816 | 15428 | 16.24 | 162.4 | 1.624 | 16.243 |
| | $f_2$ 10055 | 10829 | 11602 | 12376 | 13149 | 13923 | 14696 | 15.47 | 154.7 | 1.547 | 15.470 |
| | $f_1$ 4205 | 4529 | 4852 | 5176 | 5499 | 5823 | 6146 | 6.47 | 64.7 | 0.647 | 6.470 |
| | $f_{1\infty}$ 3991 | 4298 | 4605 | 4912 | 5219 | 5526 | 5833 | 6.14 | 61.4 | 0.614 | 6.146 |

# Meeting the mica-capacitor shortage . . .




In three sizes:
5/16" dia. x 1 3/16" long
7/16" dia. x 1 3/16" long
7/16" dia. x 1" long

## MICA-CAPACITOR *Alternates*

• An alternate choice for those hard-to-get mica capacitors in most applications—that was the problem put up to Aerovox engineers.

Various applications were studied. Voltages, capacitances, frequencies, power factor—these and other factors were considered along with dimensional limitations, after the manner of A.A.E.* Out of it all evolved this new Aerovox Type 38 mica-capacitor alternate now in production.

Here is a miniature oil-filled metal-case tubular. Ideal for assemblies where both space and weight are at absolute minimum. Requires no more space than mica capacitor it replaces. Conservatively rated. No skimping of insulation or oil-fill despite minute dimensions (see drawing). Meets all standard specifications for paper-dielectric capacitors used as mica alternates. (See brief specifications )

Type 38 mica-capacitor alternate is but one of several new wartime capacitors described and listed in our latest Capacitor Catalog. Write on business letterhead for your registered copy.

*Aerovox Application Engineering.

### FEATURES

Metal case. Double-rubber-bakelite terminal-insulator assembly.

Both terminals insulated or with one terminal grounded to case. Pigtail terminals.

Normally without outer sleeve. Can be had with insulating sleeve, adding 1/16" to diameter and length. Note dimensional drawing.

Vegetable (Hyvol) or mineral oil impregnant and fill.

300 to 800 v. D.C.W. Capacitances of .001 to .01 mfd.

Capacitance tolerances up to but not including .01 mfd. —20% +50%; .01 mfd. —10% +40%.

### OUR WAR EFFORT

From January 1941 to December 1942, Aerovox . . .

- Stepped up production output 500% for our armed forces.
- Increased production floor space 300%.
- Sought, hired, trained and put to work additional workers—a 300% increase in productive personnel.
- Opened second plant in Taunton, bringing work to available workers there.
- And—doing more and more; growing week by week!

AEROVOX *Capacitors*

INDIVIDUALLY TESTED

AEROVOX CORPORATION, NEW BEDFORD, MASS., U. S. A. • SALES OFFICES IN ALL PRINCIPAL CITIES

Export: 100 VARICK ST., N. Y. C. • Cable: 'ARLAB' • In Canada: AEROVOX CANADA LTD., HAMILTON, ONT.